

LEFE-MANU 8 Oct. 2025



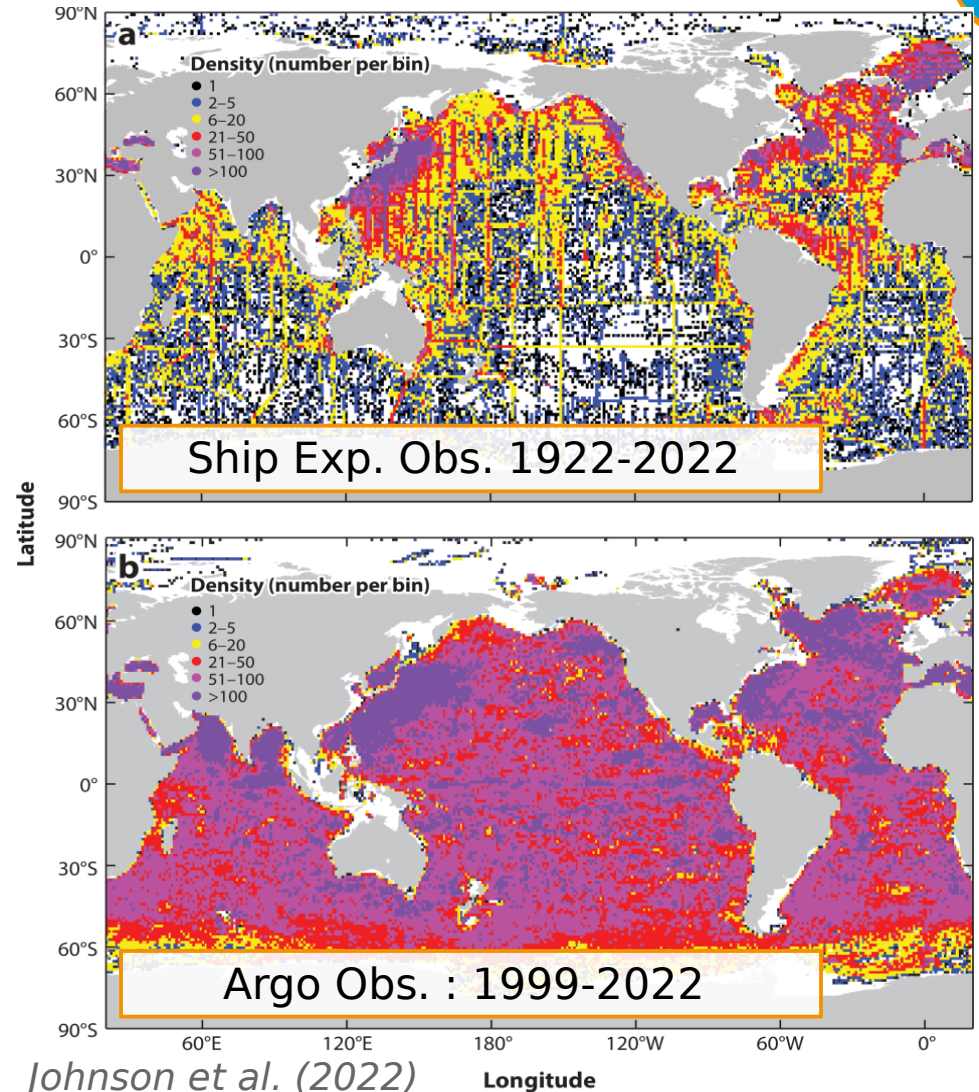
Reconstructing historical salinity changes using Argo data and data-driven method

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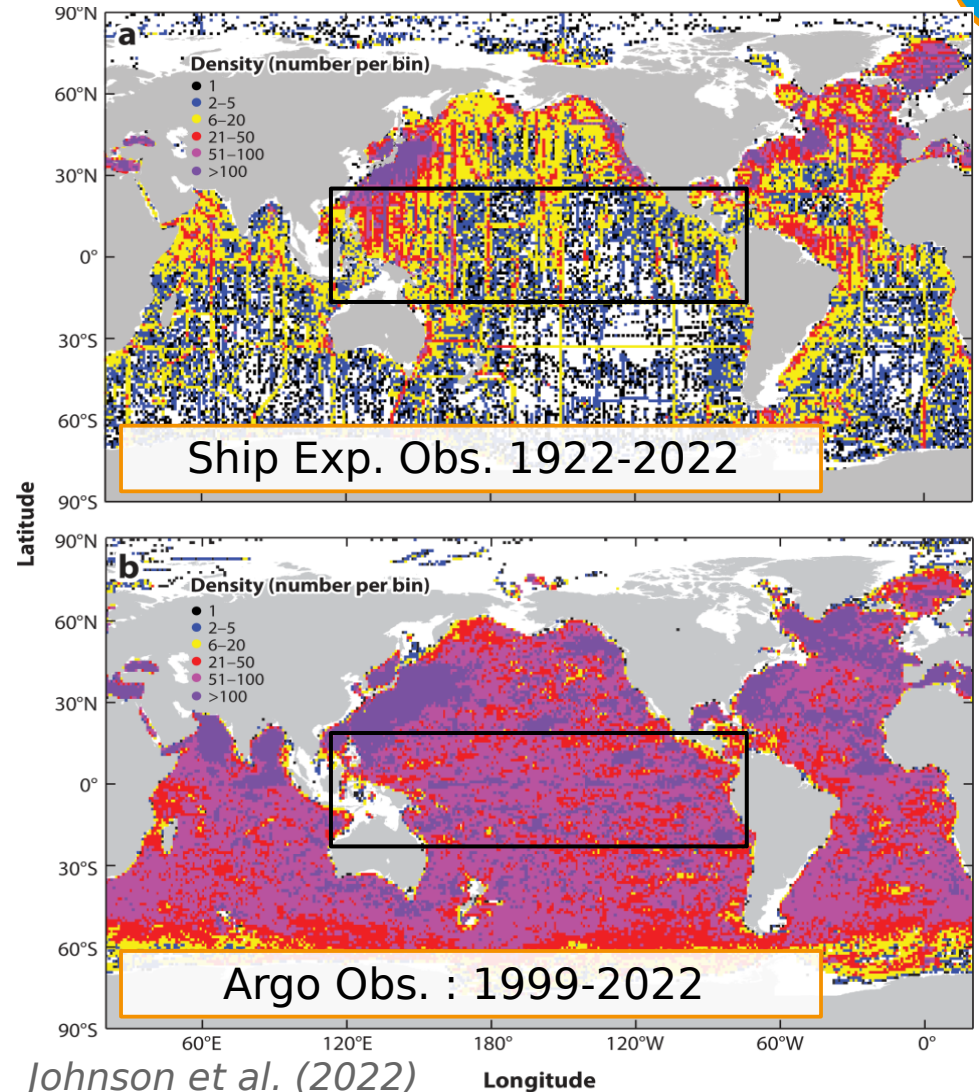
¹ LOPS, IUEM, Brest, France

² Lab-STICC, IMT Atlantique, Brest, France

- × 20th century : Too sparse observations
- × Argo period is informative, but short
- Question: how can we use the Argo period to reconstruct past ocean T/S changes?

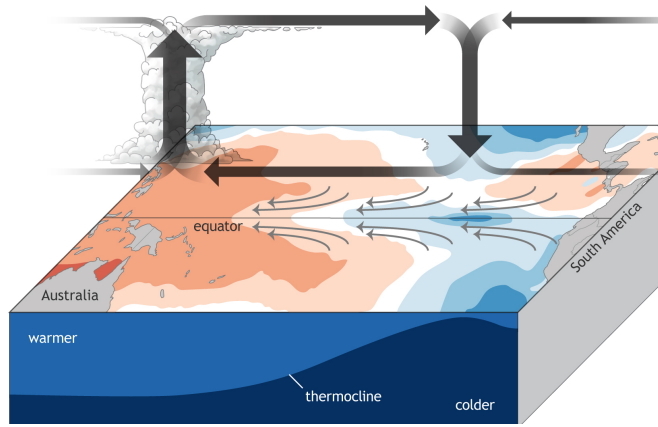


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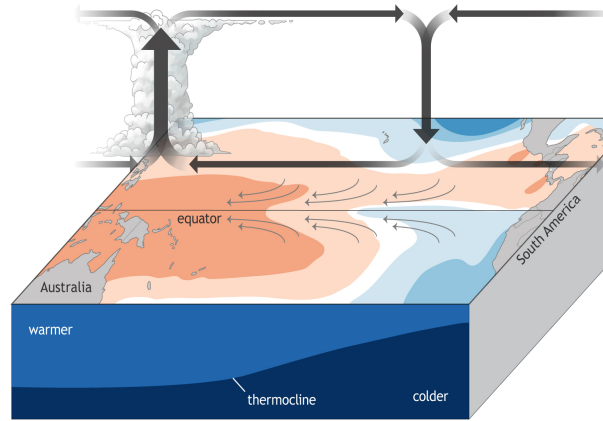


- **Exchanges of energy between ocean & atmosphere**
(Bjerknes, 1969 ; Wyrtki, 1975 ; Cane & Zebiak, 1985)
- **ENSO phases : changes in wind, advection, heat content and salinity**

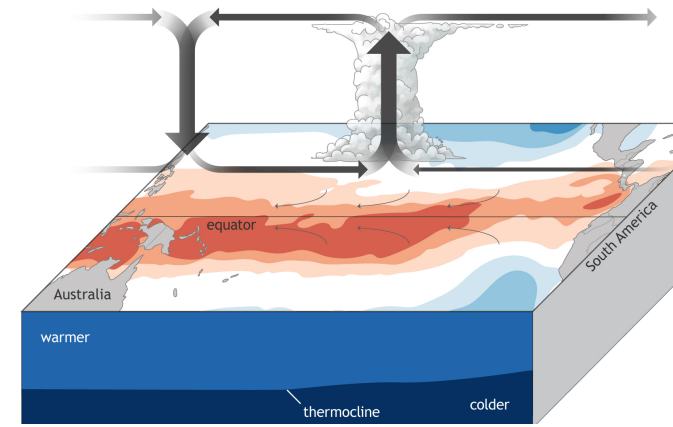
Atmosphere-ocean feedbacks during El Niño-Southern Oscillation
La Niña



Atmosphere-ocean feedbacks during El Niño-Southern Oscillation
Neutral



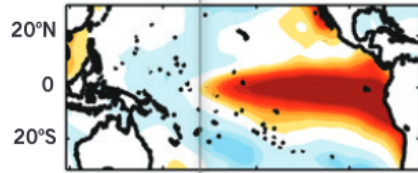
Atmosphere-ocean feedbacks during El Niño-Southern Oscillation
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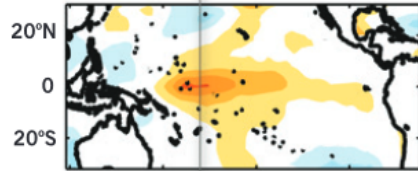
SELECTED EVENTS

to illustrate ENSO diversity
dateline 180°W

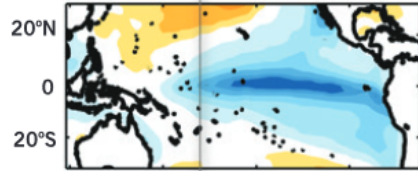
Eastern Pacific
El Nino
1997-1998



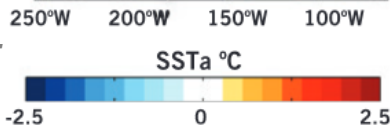
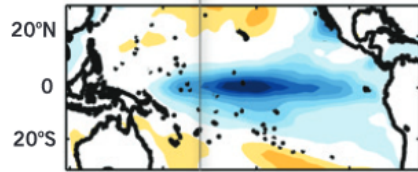
Central Pacific
El Nino
2004-2005



Eastern Pacific
La Nina
2007-2008



Central Pacific
La Nina
1988-1989

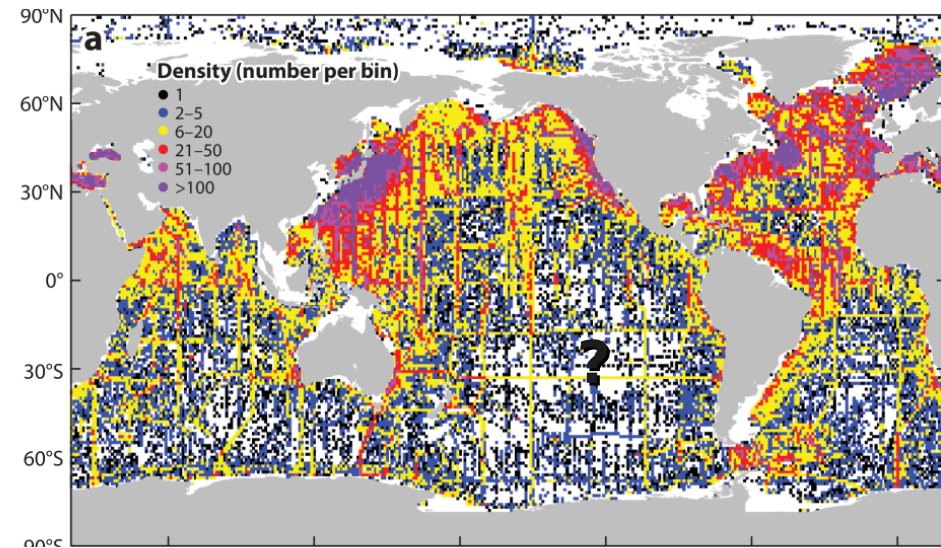


- ENSO events are diverse (intensity, frequency, length... *Capotondi et al., 2015*)
- Modulation by low-frequency variability (*Hu et al., 2022 ; Zheng et al., 2024 ; Liu et al., 2024*)
- × No long enough time series of salinity and interior of the ocean

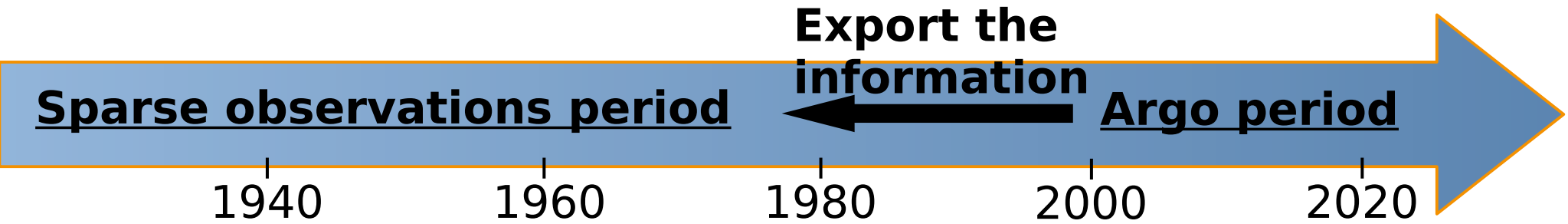
- Using statistics: Optimal Interpolation
- Dynamical simulation: Data Assimilation
- Advanced statistics: Data-driven



→ Analog Data Assimilation
(AnDA, Tandeo et al., 2015 ;
Lguensat et al., 2017 ; Zhen et
al., 2019)



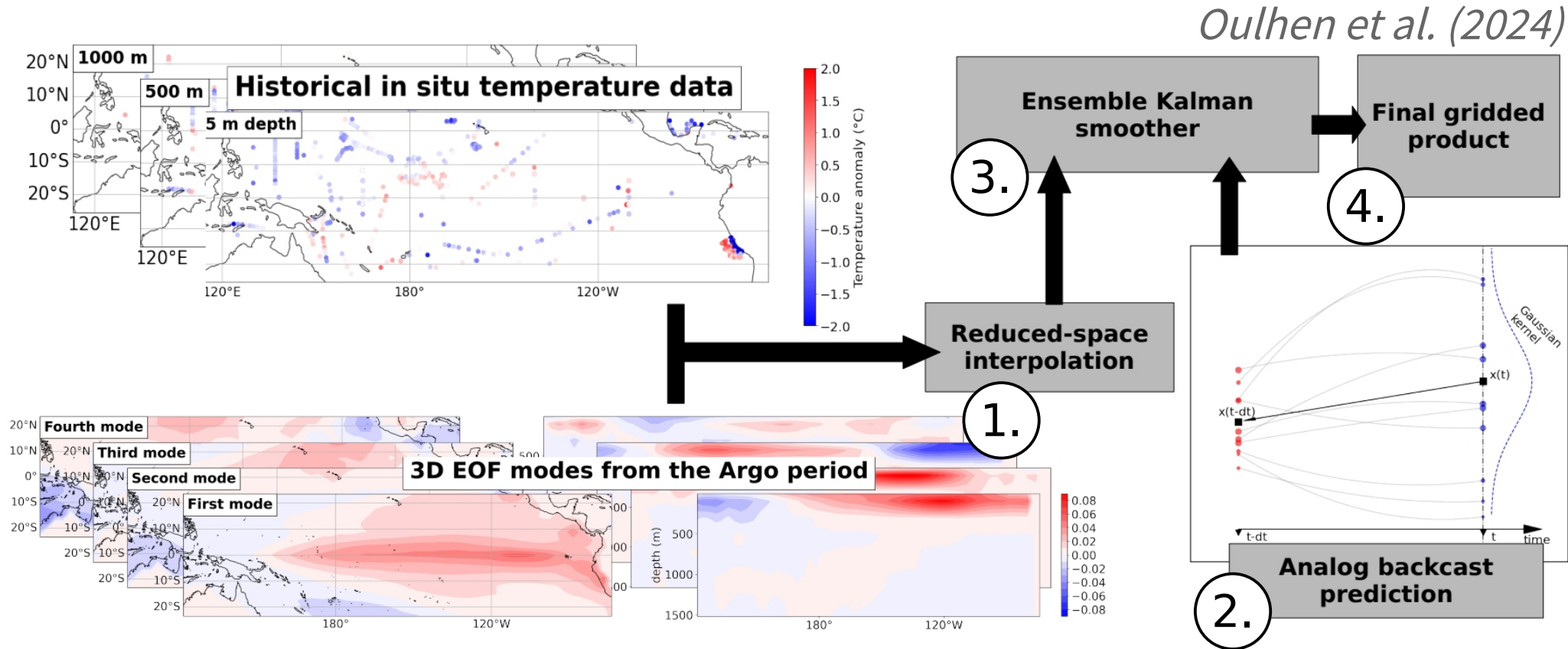
Johnson et al. (2022)



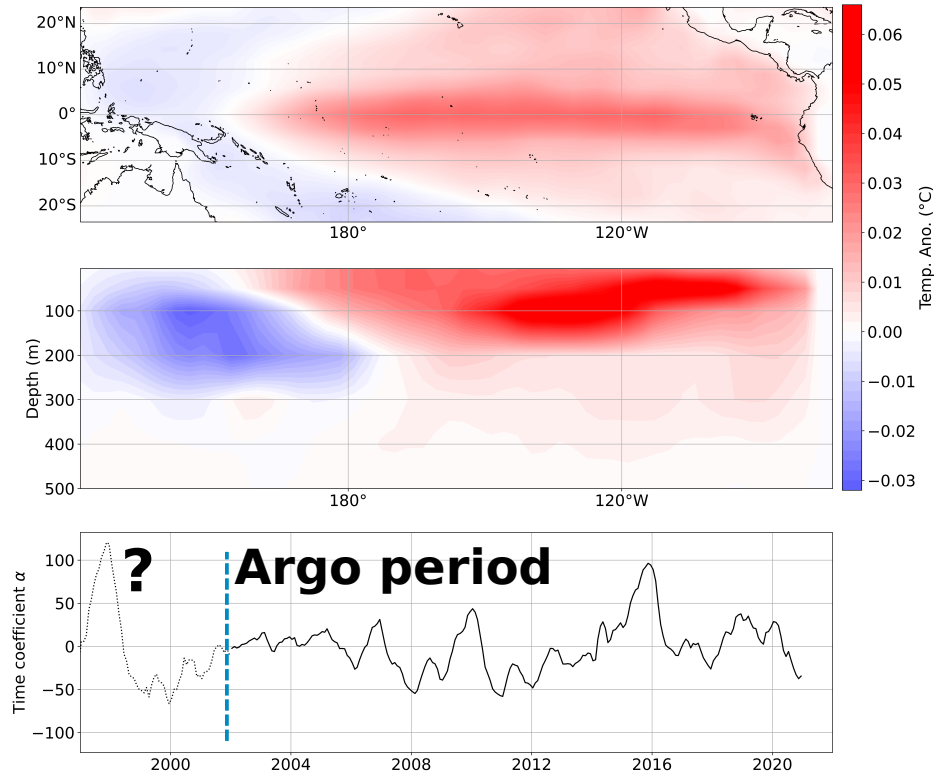
- **Catalog:** Take advantage of the Argo period
- **Analog method (Lorenz, 1969) → Backward in time prediction**
- **Space reduction: EOFs**

RedAnDA: Reduced-space Analog Data Assimilation

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First EOF at 5 m depth, and equatorial transect

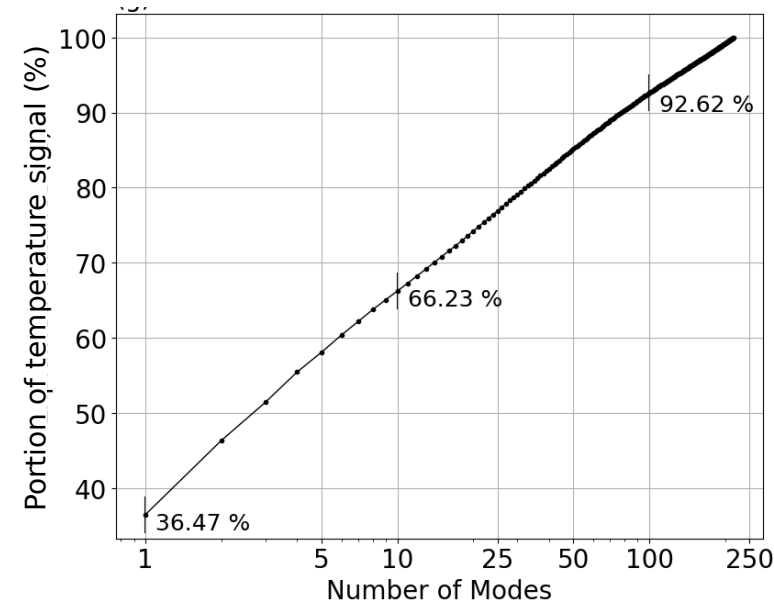


Signal approximation:

$$X(x, t) \approx \sum_l EOF_l(x) \alpha_l(t)$$

- **Advantages:** space-reduction, noise filtering, orthogonality

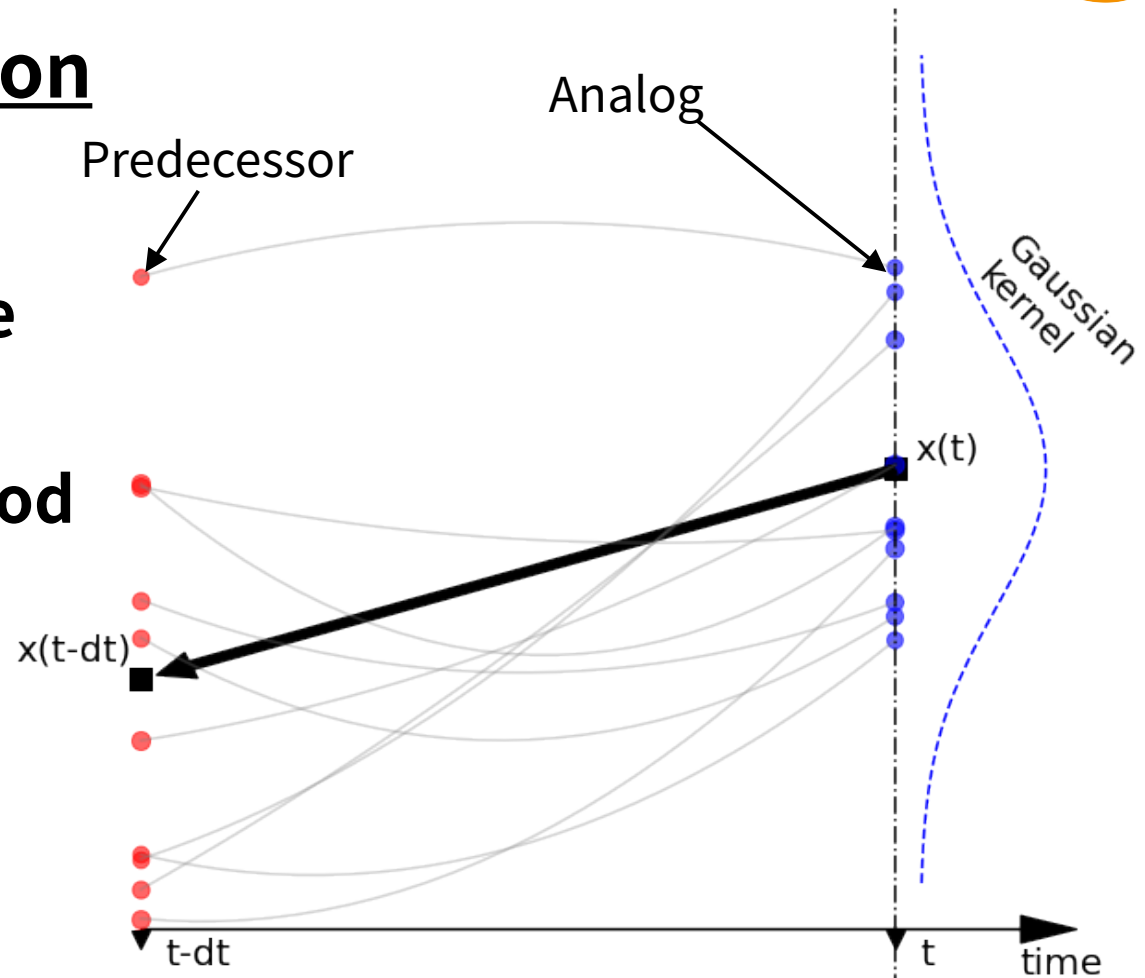
→ **Past evaluation of $\alpha(t)$**
(*Kaplan et al., 1997*)



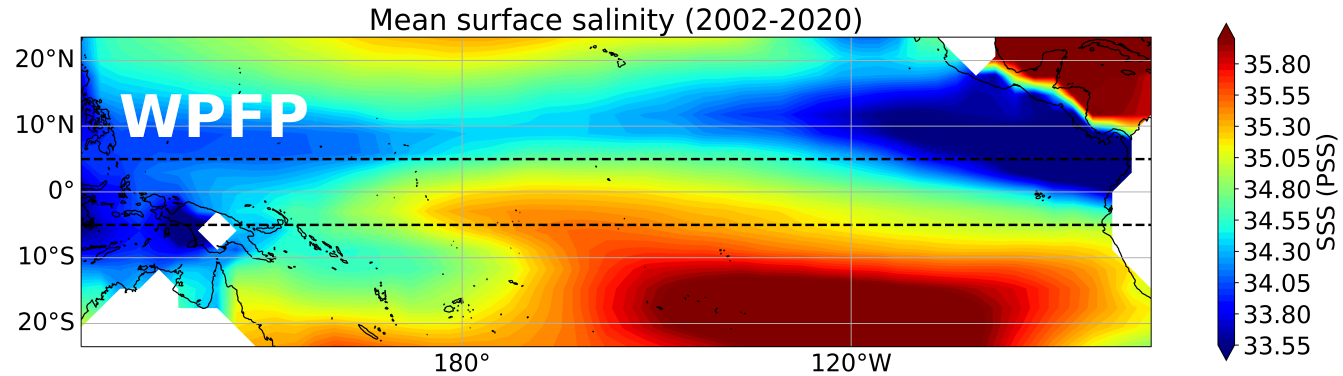
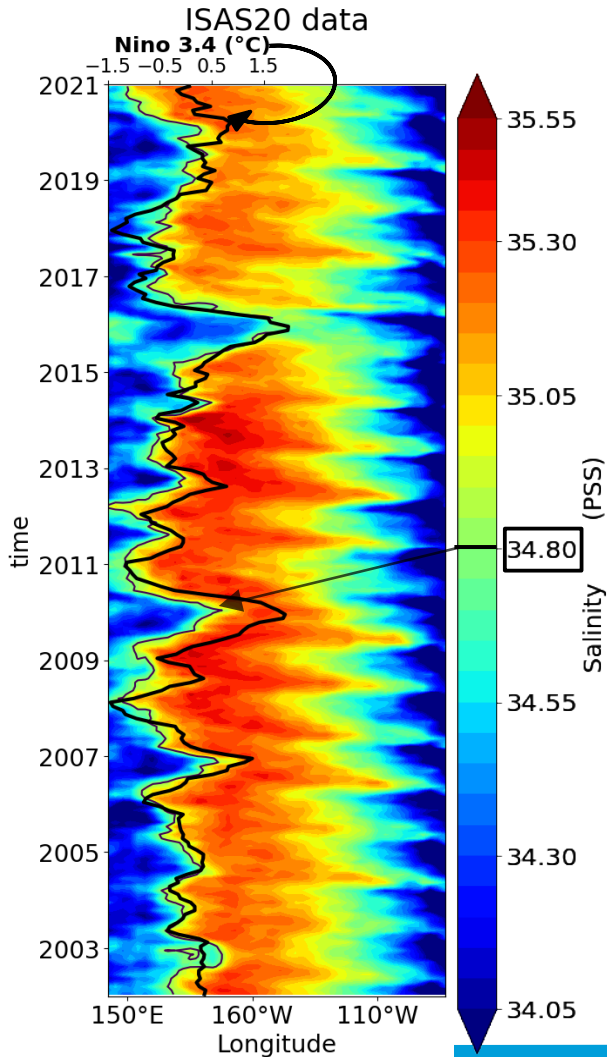
Oulhen et al. (2024)

Method : Analog prediction

- Propagate backward in time
- Catalog : from the Argo period
- Monthly resolution



- **RedAnDA was validated for temperature analysis in *Oulhen et al. (2024, JTECH)*. How does it work for salinity?**
- **Salinity application : less observations than temperature**
- **Can we use temperature to constrain salinity analysis ?**



- **Western Pacific Freshpool (WPFP) extends and retracts with ENSO events (Picaut et al., 2001 ; Qu & Yu, 2014)**
- **Coupled EOFs : represent co-occurring temperature and salinity changes**

Validation approach:

Model : NEMO (ORCA025) Source : OCCIPUT (*Penduff et al., 2014*)

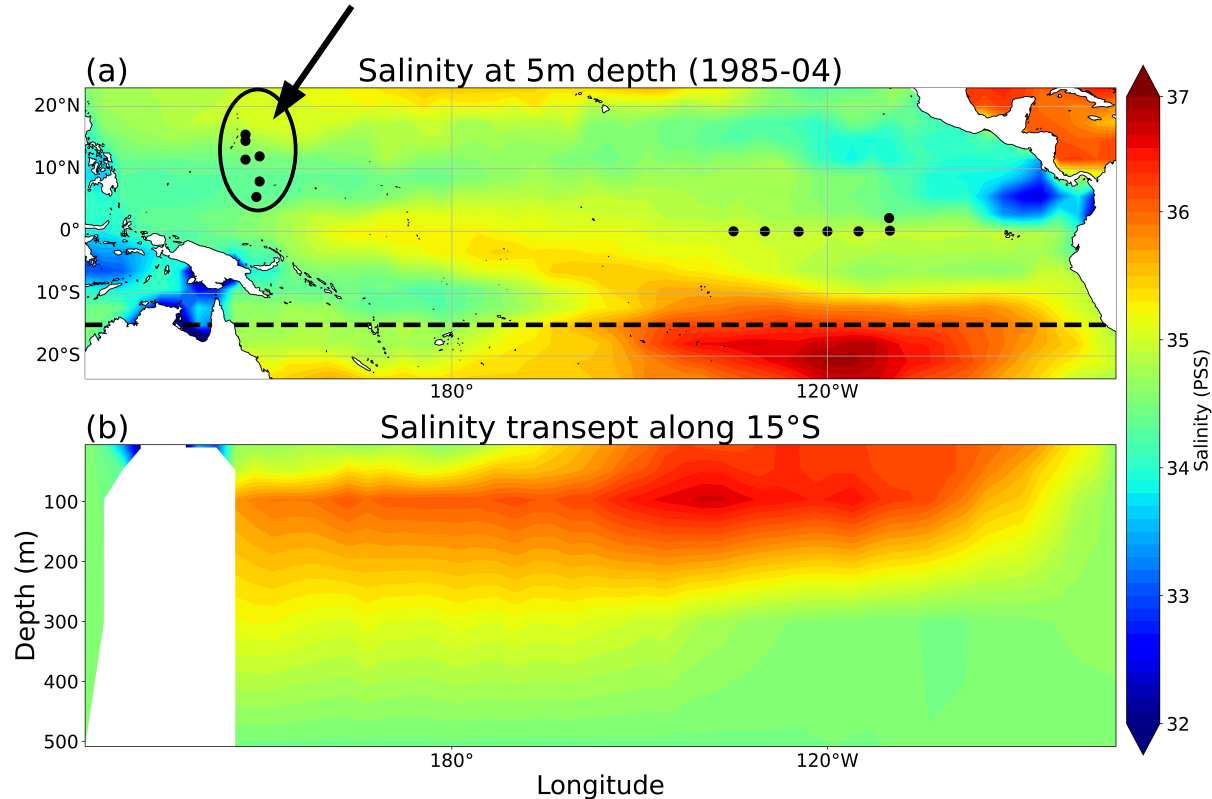
Data : T/S fields (1961-2015) and simulated historical observations.

→ Validation of RedAnDA

→ Sensitivity test: 15 EOFs

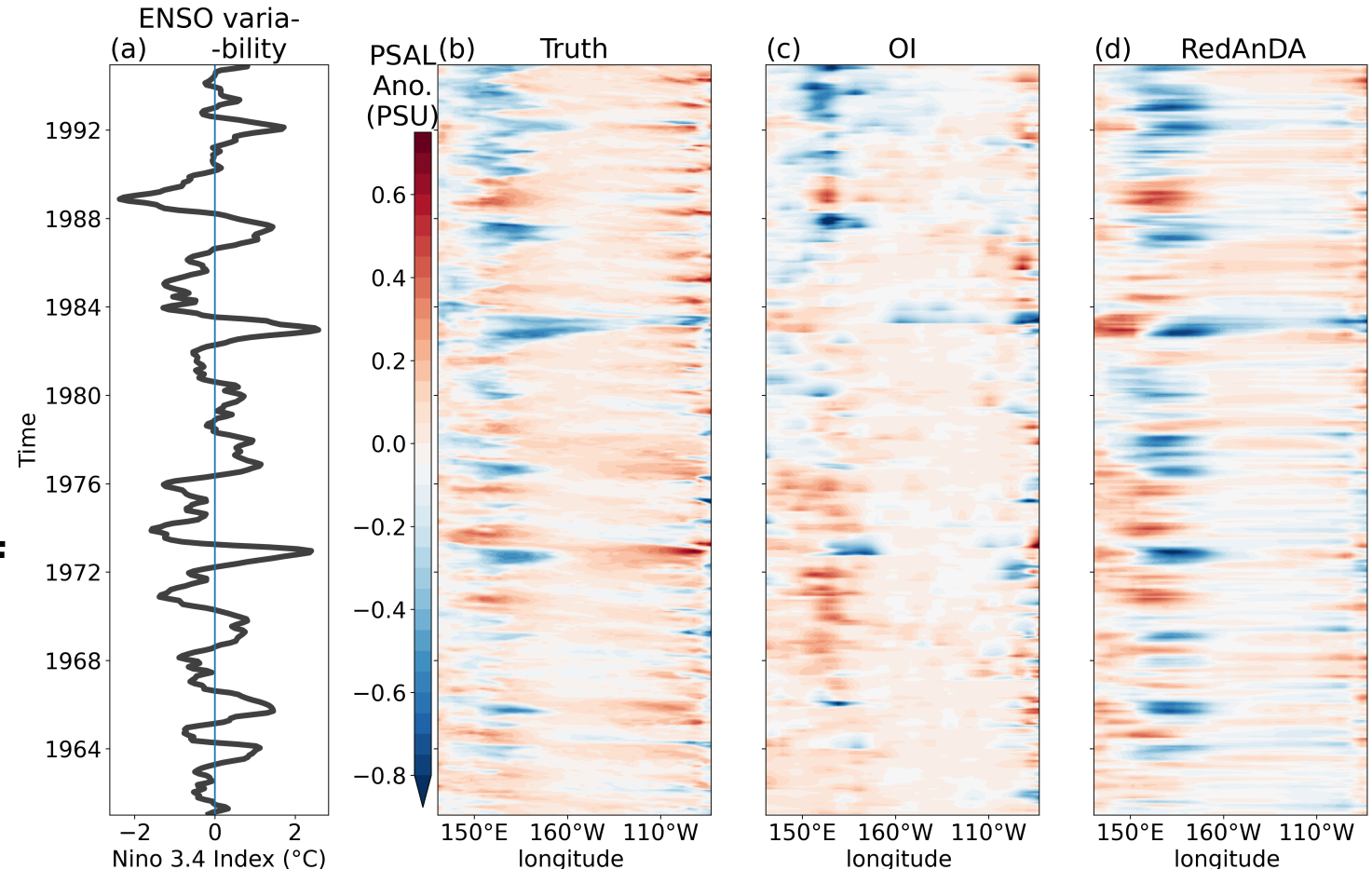
Optimal Interpolation (OI) :

State-of-the-art method (Good et al., 2013)



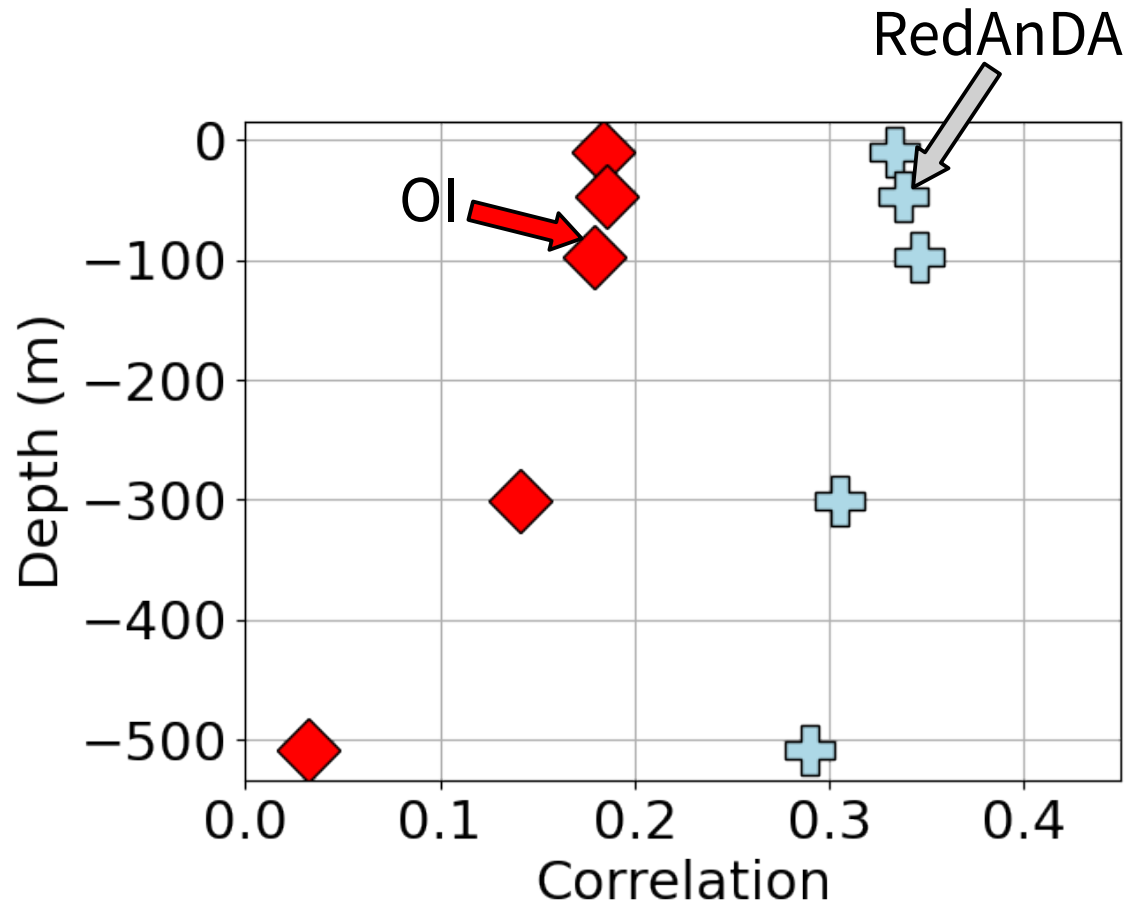
ENSO events : Sea surface salinity anomalies

- **OI limited in the absence of observations**
- **RedAnDA : good representation of ENSO events in salinity**



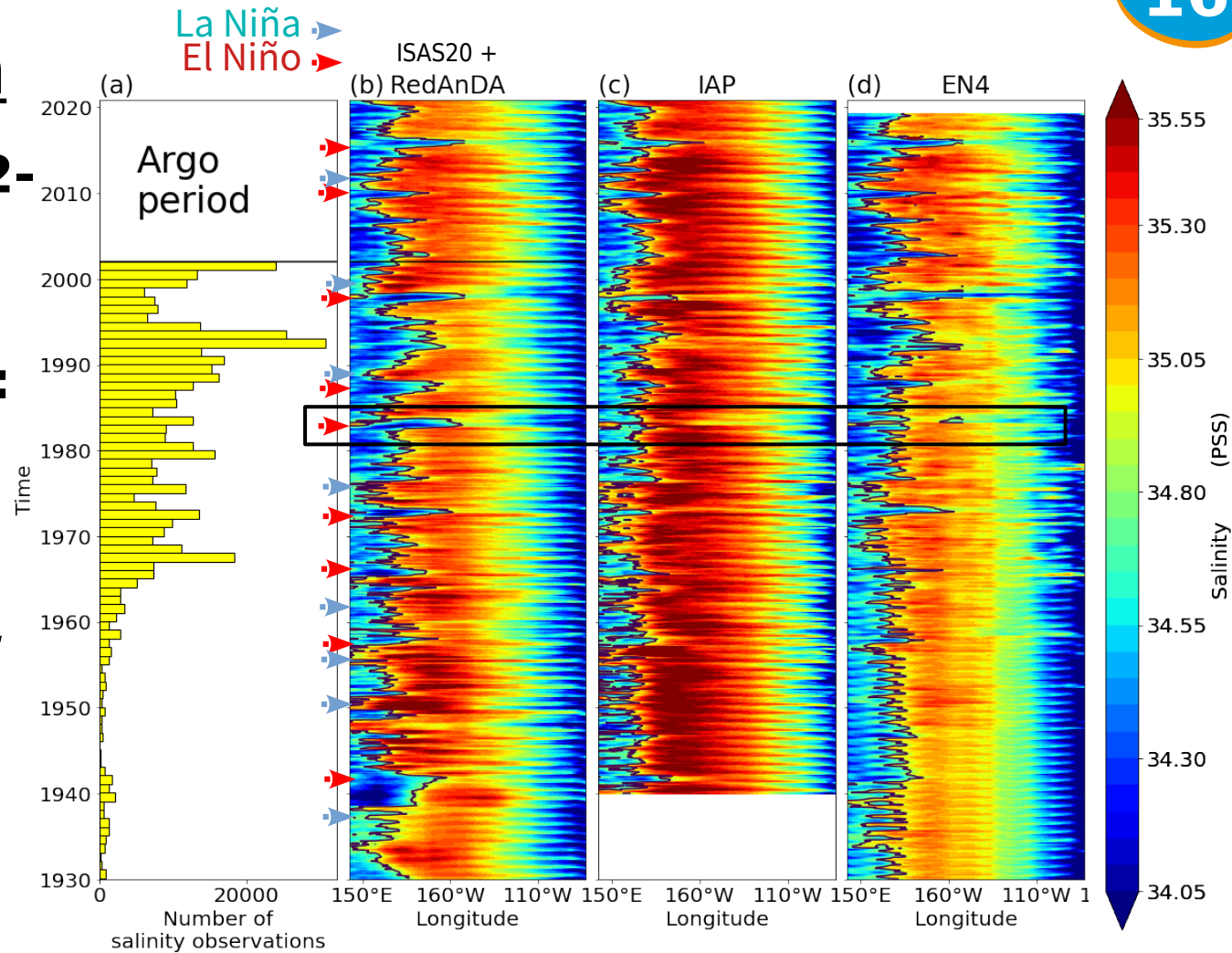
Correlation with the truth

- **RedAnDA : Better scores at all depths**
- **3D EOFs allow vertical extrapolation.**



Real data application

- **Learning period (2002-2020) : ISAS20**
(*Gaillard et al., 2016*)
- **Obs. over 1930-2001 :**
(*Good et al., 2013*)
- **Benchmarking:**
IAP (*Cheng et al., 2020*) & EN4 (*Good et al., 2013*)
- **OI methods more limited by the lack of obs.**



Conclusion

RedAnDA improves the reconstruction of interannual variations in salinity in the Tropical Pacific, in comparison with OI approaches.

Publication: Oulhen et al. (2025) *Ocean Dynamics*

DOI: 10.1007/s10236-025-01690-7

RedAnDA method: Oulhen et al. (2024) *Journal of Atmospheric and Oceanic Technology*

DOI: 10.1175/JTECH-D-23-0157.1

Datasets: On SEANOE. DOI: 10.17882/102598

Perspectives

- **Further validate the reconstruction of ENSO events, e.g., what happens at depth?**
- **Can we retrieve decadal events ?**
- **Coming Postdoc (NIOZ, The Netherlands) :
Estimation of the 20th century sea level changes.**

Ocean Salinity Stratification (OSS)

Interannual OSS fluctuations are better represented by RedAnDA, indicating more accurate vertical structure

